Sierra Nevada
Progress R

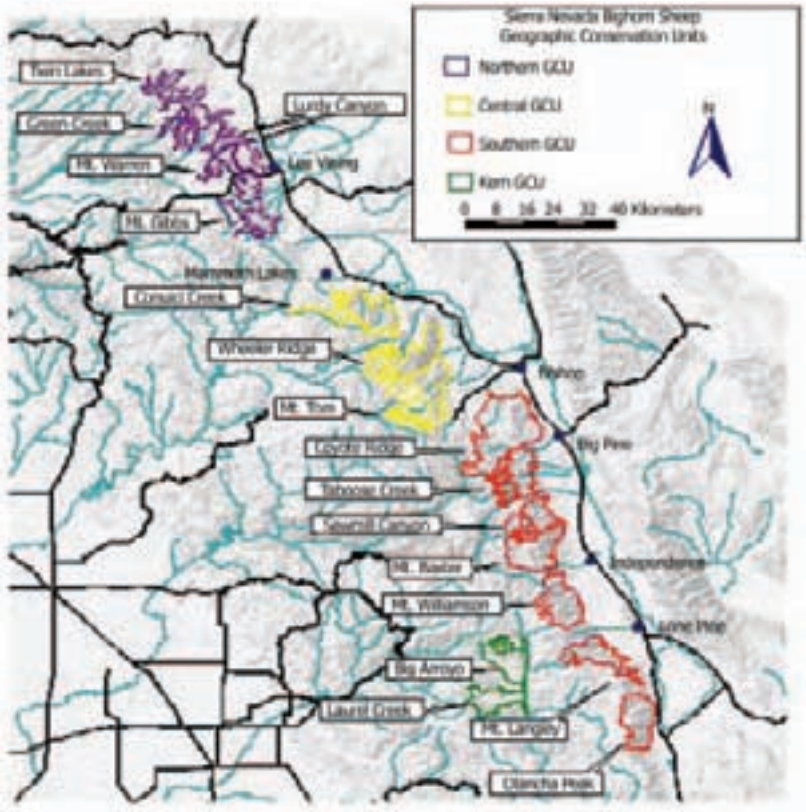
HISTORY OF SIERRA NEVADA BIGHORN SHEEP

Recent morphometric and genetic evidence suggests that bighorn sheep in the Sierra Nevada represent an evolutionarily significant unit. Indeed, this subspecies soon will undergo reclassification from *Ovis canadensis californiana* to *O. c. sierrae*. Prior to settlement by Europeans, it is likely that bighorn sheep numbered more than a thousand in the Sierra Nevada. By the beginning of the 20th century, Sierra bighorn had declined to nine known herds. By 1948, only five herds remained. Bighorn persisted in only two areas in the Sierra Nevada by the 1970s – Mt. Baxter and Mt. Williamson. Population declines were the result of two primary factors: unregulated market hunting and disease transmission from domestic sheep. Bighorn sheep in the Sierra Nevada have been protected from hunting since 1878, and some domestic sheep have been removed from areas where they might contact bighorn in the Sierra.

Between 1979 and 1988, translocations from Mt. Baxter to Wheeler Ridge, Mt. Langley, and Lee Vining Canyon expanded the distribution of bighorn to five areas of the Sierra Nevada, but numbers fluctuated between 100 and 300 animals. As a result of intensive conservation efforts and several years of favorable weather, there are currently more than 250 Sierra bighorn distributed among these five distinct areas. In order to ensure the long-term viability of Sierra bighorn, conservation goals established in the Sierra Nevada Bighorn Sheep Recovery Plan require a minimum of 365 adult female bighorn distributed among 14 herd units in four recovery units. This number and distribution is considered the minimum to sustain the population in perpetuity without human intervention.

MONITORING BIGHORN SHEEP

Intensive monitoring of Sierra Nevada Bighorn Sheep is essential to ensure their long term survival and persistence. In an effort to understand all factors that may limit bighorn population growth and their recovery, program personnel conduct monitoring not only of the bighorn population, but climatic and habitat conditions as well. Monitoring of Sierra bighorn includes field surveys to assess survival, reproduction, habitat use, nutritional condition, and movements. By attempting to fully understand the dynamics of this endangered species, we hope to avoid drastic population declines such as the one that occurred during the 1980s and early 1990s. An understanding of factors that dictate



Conservation goals include reestablishment of bighorn sheep in 14 of 17 herd units.

Bighorn Sheep eport 2003

population fluctuations may enable mitigation of critical limiting factors.

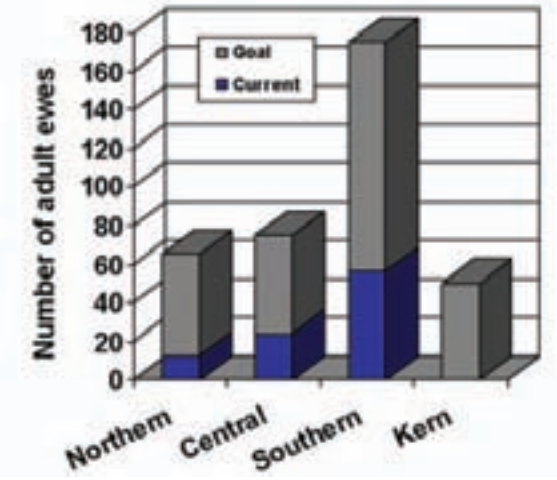
As of April 2003, 20 Sierra bighorn, distributed among five herds, wore radio-collars; 10 of those collars were remotely downloadable Global Positioning System (GPS) units. During 2002, radio-collared adult females enabled determination of lamb production and survival on Wheeler Ridge. This sample of radio-marked ewes on Wheeler Ridge indicated that six of seven (86 percent) produced a lamb and five of those six lambs survived the summer. A lamb mortality was documented during 2002 because its mother was one of the females with a GPS collar. This sample of animals appears to be representative of the remainder of the ewe population on Wheeler Ridge where over-winter mortality is

Sierra Nevada Bighorn sheep are an endangered subspecies. Note the wide flare of the horns.

Recovery goals and translocations

The Draft Recovery Plan for Sierra Nevada Bighorn Sheep establishes distributional and numerical goals. It requires occupation of 14 separate herd units distributed among four distinct regions (recovery units). For downlisting to threatened status, the numerical goals (shown right) must be met along with the removal of domestic sheep posimg a disease threat to the bighorn. For delisting, the numerical goals must be maintained within the 14 herd units for at least six years without human intervention.

Given the geographic barriers that exist, establishment of populations within all herd units will not occur within a reasonable time span without human intervention. Most importantly, translocations of animals from either productive wild populations or a captive breeding facility must occur. In 2001 and 2003, one and two rams were moved to the northern and southern recovery units, respectively. These animals were moved primarily to maintain genetic diversity. In addition, numerous translocations from the Mt. Baxter herd occurred during 1979 to 1988 and resulted in the herds at Lee Vining, Wheeler Ridge, and Mt. Langley. The immediate strategy involves moving adult females from Wheeler Ridge to Mt. Baxter in an effort to increase growth rates of the Mt. Baxter herd to support future translocations. Population modeling suggests that Wheeler Ridge can currently support the removal of at least five adult ewes and five adult rams.



Current status and numberical recovery goals for adult females in each of the recovery units.

low. We expect continued population growth in this herd. Indeed, extensive field surveys also suggest high lamb production and survival on Wheeler Ridge in 2003. In June 2003 we detected and collected our first mortality of a radio-collared bighorn since recent collaring began in 1999. A massive rock fall in Mayfield Canyon on Wheeler Ridge killed the ewe and her neonatal lamb; interestingly, this same ewe was the mother of the aforementioned lamb.

For the remainder of the herds in the Sierra, ground surveys of unmarked bighorn have been essential for population monitoring. Ground surveys of the Mt. Warren in particular, revealed that Tioga Crest adult females either failed to produce lambs, or lost them shortly after birth. Given that Mt. Warren ewes appear to spend the entire year near or above treeline (approximately 11,000 feet), we would expect them to subsist on a poorer quality diet than those animals that use lower elevation winter ranges (less than 7,000 feet) with much earlier spring green-up. In an effort to further understand the ecology of these alpine dwellers, we captured and collared one of these ewes during March 2003 and she possessed moderate levels of body fat (approximately 8 percent) and was pregnant as determined by ultra-sonography. It is noteworthy that she was in such good condition after apparently spending the entire year in that harsh alpine environment. By placing GPS collars on a number of females that live entirely in the alpine, we hope to learn more about their behavior, particularly their foraging habits.

In the southern recovery unit, we captured and collared two ewes, one using the Sawmill Canyon winter range and one using Black Canyon winter ranges.

Those radio-collared animals will enable monitoring of seasonal movements, such as arrival on winter and summer ranges, and will facilitate evaluation of the potential risk of predation from mountain lions. As more ewes are radio-collared, personnel will be able to gather detailed information on survival and lamb production.

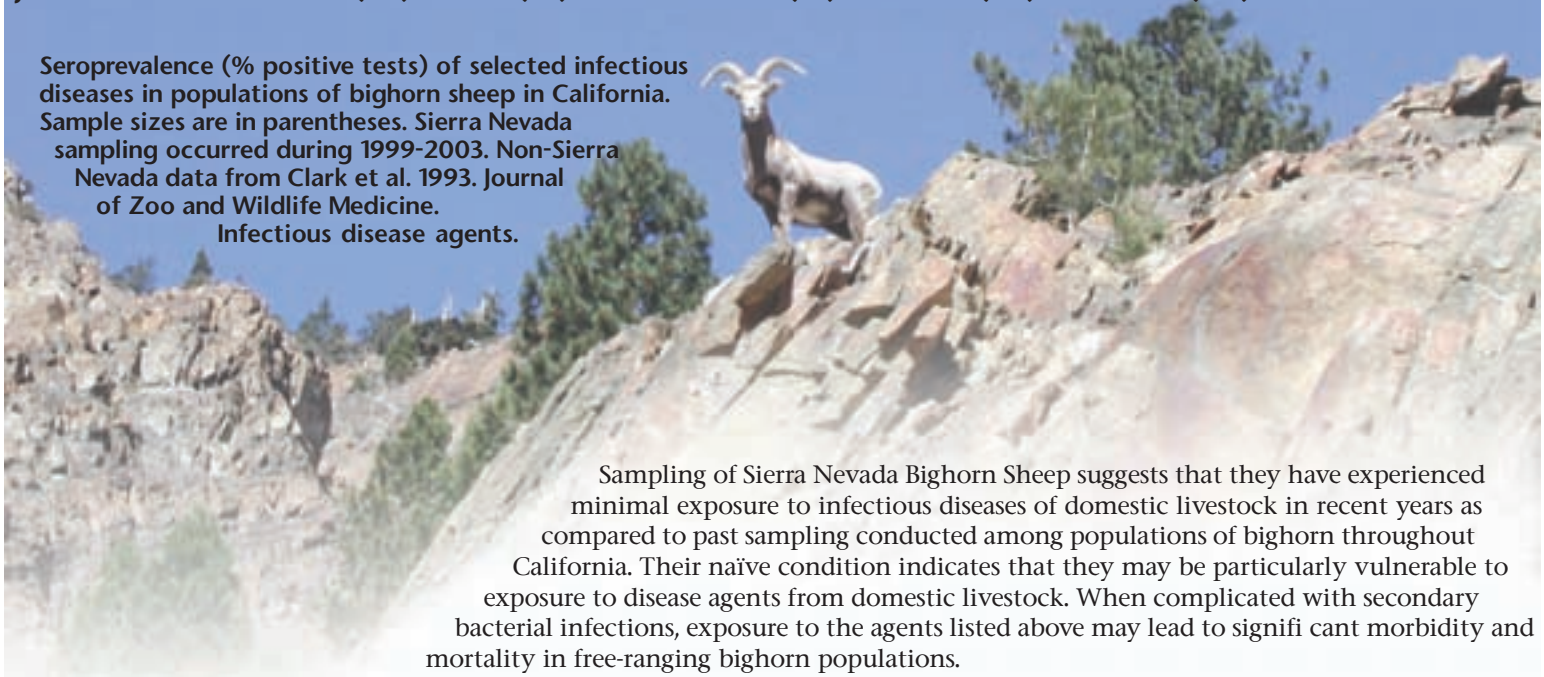
Results of monitoring efforts Jan. - Dec. 2002 based on direct counts and fecal genetic analysis

RU	Herd	Estimated Pop.	# of ewes	Monitoring person days
North	Warren	28	8	56
	Gabbs	9	3	4
Central	Wheeler	63	24	212
South	Baxter		20	79
	Sawmill		6	10
	Gardiner	16	?	10
South	Williamson	30	15	21
South	Mt. Langley	40	13	35

Disease prevalence among populations of bighorn sheep in California

Population (s)	Bluetongue Virus	Bovine Respiratory Syncytial Virus	Contagious Ecthyma Virus	Epizootic Hemorrhagic Disease	Para-Infl uenza Virus	Chlamydia
Wheeler Ridge	0 (17)	0 (17)	0 (10)	6 (17)	0 (17)	4 (11)
Lee Vining	0 (3)	0 (3)	0 (2)	0 (3)	0 (3)	2 (3)
Mt. Baxter	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)
White Mts.	0 (9)	13 (8)	0 (4)	0 (9)	20 (20)	17 (6)
San Gabriel Mts.	4 (73)	0 (60)	0 (11)	4 (72)	1 (72)	
Chocolate/ Orocopia/ Chuckwalla Mts.	36 (25)	17 (24)	67 (3)	36 (25) 1	6 (25)	86 (7)
Santa Rosa Mts./ Joshua Tree	43 (121)	18 (49)	54 (77)	52 (101)	20 (124)	

Seroprevalence (% positive tests) of selected infectious diseases in populations of bighorn sheep in California. Sample sizes are in parentheses. Sierra Nevada sampling occurred during 1999-2003. Non-Sierra Nevada data from Clark et al. 1993. Journal of Zoo and Wildlife Medicine. Infectious disease agents.



Sampling of Sierra Nevada Bighorn Sheep suggests that they have experienced minimal exposure to infectious diseases of domestic livestock in recent years as compared to past sampling conducted among populations of bighorn throughout California. Their naïve condition indicates that they may be particularly vulnerable to exposure to disease agents from domestic livestock. When complicated with secondary bacterial infections, exposure to the agents listed above may lead to signifi cant morbidity and mortality in free-ranging bighorn populations.

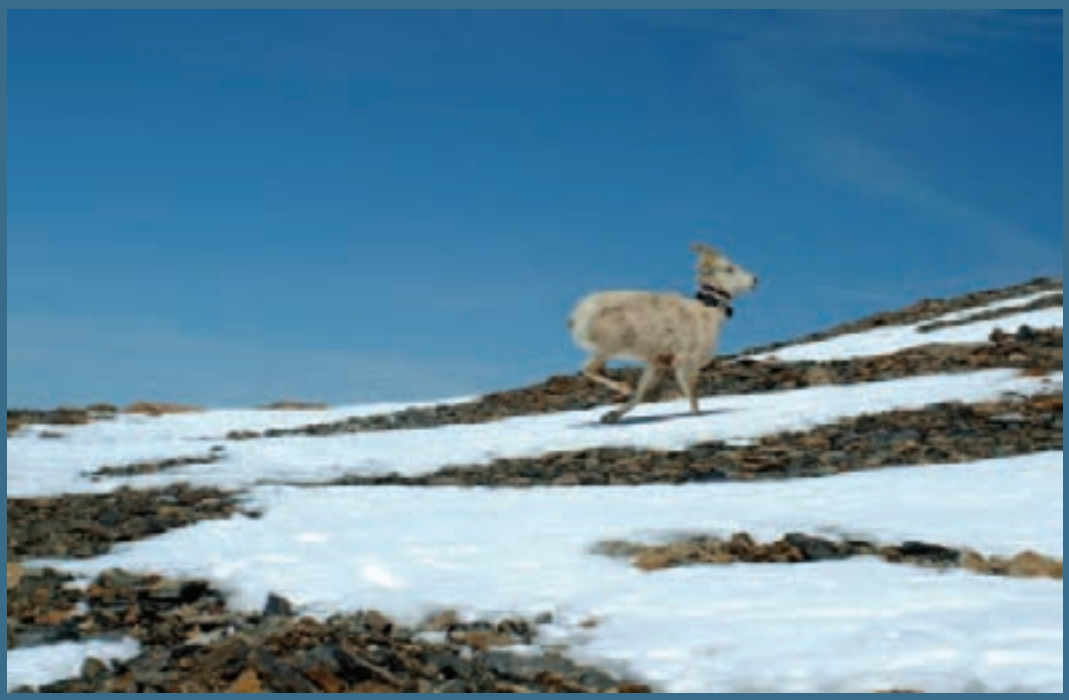
Evaluating carrying capacity for Sierra Nevada Bighorn

How many bighorn exist in the Sierra Nevada, and where are they? We have a general idea but it would be useful to know more precisely. Current efforts to approximate carrying capacity (the number of animals that an area can support) focus on two approaches: the forage-based approach, and the animal indicator approach. We are applying both approaches to some extent within the program.

The forage based approach requires determining forage quantity and quality on a range and then applying estimates of an animal's nutritional requirements to arrive at an estimate of the number of animals that the forage base can support. Efforts to do this are expensive and often produce results with low precision. With recent advances in remote sensing that produce high-resolution vegetation maps with satellites and aircraft, it is possible to quantify broad availability of winter and summer range habitats, establish their connectivity, and determine their acceptability to bighorn based on proximity to terrain that is safe from predators.

In contrast, the animal indicator approach uses the body condition and reproductive success of an animal to determine the quality of that animal's environment. In particular, nutritional condition, typically measured as body fat, is directly related to the quality of diet consumed by an animal. Therefore, when animals are captured for purposes such as radio collaring, it provides an opportunity to measure body fat and determine pregnancy status through the use of ultrasonography.

Nutritional condition measured during late winter reflects most directly winter forage conditions and winter severity, whereas fall measurements are indicative of summer forage quality and lactation status. Validation studies enable us to predict total body fat from subcutaneous fat measured by ultrasound in live animals. Other measures (various blood, urine, and fecal metabolites) relate to nutritional status; however, these techniques provide information only about diet quality experienced several days prior to sample collection. Such measures may be useful as a supplement to body condition data.



Ultrasonography of an adult ewe, which wintered at over 11,000 ft., revealed that she was in surprisingly good body condition. This has raised questions about the energetic costs of over-wintering at high elevation for Sierra bighorn sheep.

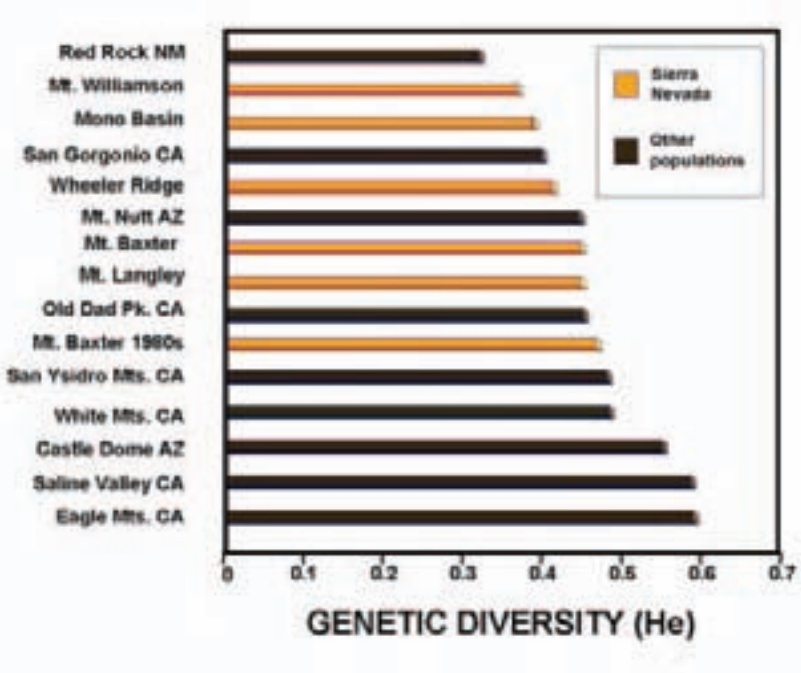
Nutritional condition has the potential to reveal much about the carrying capacity of an area, as well as when density-dependent competition for food occurs. Through long term monitoring it should be possible to use nutritional condition to detect density dependence and ensure that animals do not overpopulate a range, making a population more susceptible to devastating declines. Clearly, carrying capacity and forage supply directly relate to annual precipitation, particularly in the eastern Sierra, and by monitoring weather in conjunction with nutritional condition we can decipher the effects of weather (density independent) and animal density (density dependent) on forage.

Bighorn population genetics

We have been developing large data sets regarding genetic questions concerning Sierra Nevada Bighorn Sheep with techniques that use fecal samples as the source of sheep DNA. This has eliminated the need to handle sheep to obtain DNA and, thereby, has allowed us to sample populations from which it might otherwise be impossible to obtain DNA. Individual sheep can be identified by their genetic profiles, which eliminates the potential problem of sampling the same sheep multiple times. Because individual identities can be recognized genetically, this approach has been used to supplement field observations used for population monitoring.

Two population-level questions are being pursued with molecular genetic techniques. One concerns the apparent morphological and genetic distinctness of Sierra Nevada Bighorn Sheep compared with populations east across the Owens Valley and further distant across the deserts of California and neighboring states. Data emerging from the current research indicate that this is not such a strict division. Genetic forms found east of the Owens Valley appear in low frequency in the Sierra Nevada and the Sierra Nevada form occurs occasionally east of Owens Valley. Nevertheless, there remains a major genetic difference between the sheep on either side of the Owens Valley.

The second question concerns levels and trends in genetic diversity in the Sierra Nevada. The long history of population losses and population crashes for the surviving populations is a situation expected to lead to losses of genetic diversity. This subject is being pursued by sampling existing herds in the Sierra Nevada and making comparisons with populations east of the Owens Valley and other populations in the Southwest, as well as with one population in the Sierra Nevada (Mount Baxter) from the early 1980s when it was large and served as the source of translocation stock for the three translocated herds (Wheeler Ridge, Mt. Langley, and Mono Basin). The results to date indicate that Sierra Nevada populations at the lower end of genetic diversity measures for extant populations have less genetic diversity than other populations of bighorn sheep where a genetic record exists. Only a captive herd in New Mexico with a known history expected to significantly reduce genetic diversity was lower than the lowest of those in the Sierra Nevada. Two herds in the Sierra Nevada (Mono Basin and Mount Williamson) show notably lower genetic diversity than the rest. This information can be used in a focused approach to genetic management in attempts to stop and reverse the downward trend in genetic diversity in those herds.



Sierra Nevada bighorn have a lower genetic diversity than most other populations; only a captive herd in New Mexico is lower.

Petroglyph of bighorn sheep.

Investigating lamb survival: An example of remote-download GPS technology

On May 11, 2002, a dead lamb less than one-week-old was discovered at approximately 10,800 ft. elevation in Huarte Canyon on Wheeler Ridge. The lamb was believed to belong to a GPS-collared ewe that was determined to be pregnant by utrasonography at her capture in March.

The loss of her lamb was discovered after evaluation of movements determined by remote query of the ewe's GPS collar on May 9, 2002. The ewe spent about two weeks in Huarte Canyon, including a period of restricted movement at the top of the canyon (April 24 to 29), that appeared consistent with the timing and expected immobility of neonatal Sierra Nevada Bighorn Sheep. This cluster of activity was followed by the ewe's rapid movement of less than 4 miles north on Wheeler Ridge, a distance greater than a newborn would be expected to move.

A closer look at the ewe's movements at the end of April revealed a cluster of points, including multiple fixes at the same point separated by less than two days. After climbing to this location to investigate, program personnel found the dead neonate. The carcass was intact with no sign of predation and minimal scavenging (a jay helped pinpoint the lamb). The lamb's head was wedged snout-down between 2 boulders and its neck acutely luxated such that the snout pointed back towards its abdomen. Rocks in the talus patch appeared chalky on the corners, consistent with a recent slide. A necropsy was performed at the California Department of Fish and Game's Wildlife Investigations Laboratory, and cause of death found to be consistent with trauma sustained during a rock slide.